

Full Length Research Paper

Diversity, abundance and incidence of fruit pest insects on three *Solanum* varieties (Solanaceae) in two agro-ecological zones of Southern Cameroon

Elono Azang Pierre Stephan^{1,2}, Aléné Désirée Chantal¹, Heumou Cyril Roméo^{1,3}, Ngassam Pierre⁴ and Djiéto-Lordon Champlain^{1*}

¹Laboratory of Zoology, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, P. O. Box 812 Yaounde, Cameroon.

²Laboratory of Zoology, Department of Biological Sciences, Higher Teacher's Training College, University of Yaounde I, P. O. Box 47 Yaounde, Cameroon.

³Department of Biology, Higher Teacher's Training College, University of Bamenda, P. O. Box 39 Bamenda, Cameroon.

⁴Laboratory of Parasitology and Ecology, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, P. O. Box 812 Yaounde, Cameroon.

Received 10 May, 2016; Accepted 17 August, 2016

Various species and varieties of the genus *Solanum* (Solanaceae) are among the most important market crops produced worldwide. They may be considered as multipurpose crops since leaves and/or fruits are eaten fresh or cooked in various dishes. The increase of garden surfaces and the permanence of gardening have induced frequent outbreaks and diversification of pests and cryptogrammic diseases. In order to improve farmer's capacities in controlling these constraints, the present study assessed diversity, abundance and incidence of fruit pests on *Solanum* spp. Data collection was conducted in two agroecological zones of southern Cameroon: Okola (Center Region) and Koutaba (Western Region), on three plant varieties from the genus *Solanum*: *Solanum aethiopicum* (African scarlet eggplant) with two varieties (jakatu and zong) and *Solanum melongena* (brinjal eggplant) var. inerme. The study aimed to (1) characterise the community of fruit pests associated with these plant varieties, (2) assess damage due to the main pests and (3) determine their impact on fruit yield. To achieve this, systematic sampling were done by visual observations in experimental gardens set up at the above cited sites. Harvests and incubations of infested fruits allowed identifying 15 insect species, belonging to three orders and 12 families: Lepidopterans with *Leucinodes orbonalis*, *Cryptophlebia leucotreta*, *Helicoverpa armigera*, *Chrysodeixis chalcites* and *Hypolycaena phyllippus*), Dipterans with *Batrocera* (*Batrocera*) *dorsalis*, *Ceratitis* (*Ceratitis*) *capitata*, *Ceratitis* (*Pterandrus*) *anona*, *Neosilba* sp., *Atherigona* sp. three unidentified species belonging to undetermined genera and Coleopterans with *Diplognatha gagates* and *Formicomus* sp.. Among them, *H. phyllippus* and *C. chalcites* were absent from Koutaba's samples. Without site considerations, *L. orbonalis* was the most abundant with higher incidence on fruit production. At Okola, fruit losses on *S. aethiopicum* var. jakatu, on *S. aethiopicum* var. zong and on *S. melongena* var. inerme were 53.8-76.97, 43.65-61.51 and 29.42-46.61% respectively while at Koutaba, they were 49.51-68.57, 33.41-60.23 and 11.68-30.44%. The present study provided baseline data for integrated pest management strategies of *Solanum* in Cameroon.

Key words: *Solanum*, yield, fruit pests, *L. orbonalis*, damages.

INTRODUCTION

The increase of market crop trade in national and sub-regional markets has led to intensification of gardening in various production basins in Cameroon. Among crops involved are various species of the genus *Solanum* (Solanaceae) that includes species of high nutritional and sociocultural values. Fruits and vegetables production in Cameroon provides 154 billion of CFA francs (representing about 3% of the country's GDP 1997/1998). These incomes constitute a great component in the fight against poverty (Temple, 2001). The gardening faces important threats among which the presence of insect pests that include mainly dipteran and lepidopteran fruit feeders. Eggs are laid on various parts of the plant for lepidopterans or under the fruit cuticle for dipterans. After hatching, larvae develop in the fruit pulp from which they leave at the pre-nymph stage to pupate in the soil. Because larvae feed and live inside the fruit, they cannot be effectively controlled by contact insecticides (Djiéto-Lordon and Aléné, 2002, 2006), while systemic insecticides are not appropriate for vegetables. In these conditions efficient control strategies may associate appropriate use of pesticides with other control techniques such as biological control, mass trapping, or physical and biotechnology control techniques in integrated pest management strategies. Implementation of these strategies needs a good knowledge of insects diversity in the ecosystem and the ecology of the pests. In this framework, the present study aimed to gather baseline data necessary for improvement of pest control strategies, the present study aimed to characterize fruit pests on three plant varieties belonging to two species of the genus *Solanum*, commonly grown in the Central and West African sub-regions: (1) The highly economic potential crop *S. aethiopicum* with two varieties, the var. zong (Figure 1a to c) and the var. jakatu (Figure 1 d to f). The first variety is among the most important native varieties cultivated in the forest region of Central Africa. Despite its weak commercial value, it is a great component of various unsalted meals e.g. 'Sanga', 'Kpwem' (Franqueville, 1972). The second variety, also called sweet *Solanum* constitutes a significant source of income for farmers and retailers in urban and peri-urban zones and can be encountered in almost all the markets in West and Central Africa, where it is one of the five most important vegetables (Adeyeye and Adanlawo, 2011); its fruits are rich in vitamins and minerals and are consumed fresh, dried or transformed into association with other vegetables (salads), cooked in soup or boiled (Messiaen, 1989; Lester and Seck, 2004; Shippers 2004). (2) The third variety is *Solanum melongena* var. inerme (Figure 1 g to i). It is less known than the two

others, but is an important component of traditional and highly valuable meals of the western highlands of Cameroon, e.g. 'Yellow soup', 'Nah poh' and 'Nkui soup' (Noumi, 1984; Tchiégang and Mbougoueng, 2005).

The species *S. aethiopicum* is a plant of sunny area distributed throughout the southern Cameroon and other countries in Africa (Sekara et al., 2007). Its phenology is closely correlated with the local climatic conditions. During the rainy season, the plant has a greenish appearance with several leaves and maturing fruits while in the dry season, it has a jagged appearance (Schippers, 2004). The var. zong of *S. aethiopicum* and inerme of *S. melongena* grow well in full sunny woodland on relatively well drained deep soils with a pH of 5.5 to 6.8 and temperatures ranging from 25 to 35°C during diurnally and 20 to 27°C nightly. The var. jakatu of *S. aethiopicum* grows in warmer climates (45°C during the day) but may tolerate relatively dry conditions with sometimes less than 20% moisture (when irrigated) (Grubben and Denton, 2004; Schippers, 2004).

Despite highly nutritional, cultural and commercial values, few studies have focused on the diversity and geographic distribution of fruit pests of *Solanum* spp. in southern Cameroon (Djiéto-Lordon and Aléné, 2006; Djiéto-Lordon et al., 2007). The aim of the present study, conducted in two agroecological zones of southern Cameroon, Central plateau and Western highlands were: (i) To identify the insect pests associated with the fruit of three *Solanum* varieties; (ii) To assess host specificity of the pests on the three plant varieties, and finally, (iii) To evaluate the incidence of each specific fruit pests on the yield of each variety.

MATERIALS AND METHODS

Study site

Field study was carried out simultaneously in two localities from two agro-ecological zones of southern Cameroon: Okola (04°01'39.0"N, 011°23'00.1"E, asl: 604 m) in the Southern plateau, and Koutaba (05°38'47.9"N, 010°48'22.2"E, asl: 1186 m) in the Bamoun Plateau. The latter is situated in one of the main market crop basin of Cameroon (Westphal et al., 1981). Both agroecological zones differed in their topographic and climatic characteristics. At Okola, the study area undergoes an equatorial climate with bimodal rainfall regime marked by a succession of four seasons while Koutaba is under a humid tropical climate characterized by two seasons with unimodal rainfall regime (Suchel, 1988). For landscapes, more description and climatic conditions of the study sites, is found in Mokam et al. (2014) and Heumou et al. (2015). The study period extended from June 2010 to October 2011 at Okola and from August 2010 to November 2011 at Koutaba.

*Corresponding author. E-mail: champlain_djiéto@yahoo.ca. Tel: (+00237) 675 04 33 33.

Author(s) agree that this article remain permanently open access under the terms of the [Creative Commons Attribution License 4.0 International License](https://creativecommons.org/licenses/by/4.0/)

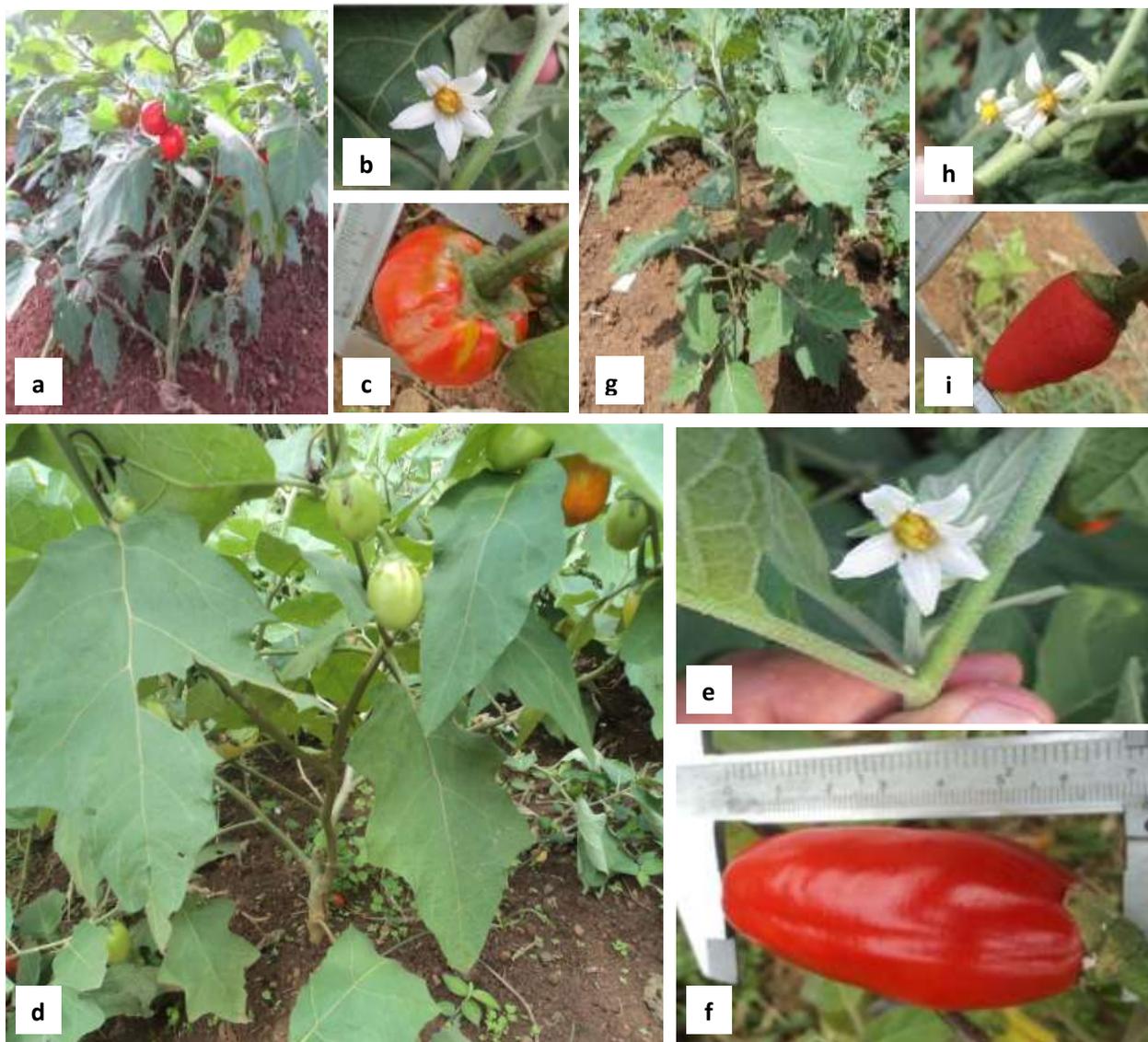


Figure 1. *Solanum* species involved in the study. (a) plant, (b) flower, (c) fruit of *S. aethiopicum* var. zong; (d) plant, (e) flower, (f) fruit of *S. aethiopicum* var. jakatu and (g) plant, (h) flower, (i) fruit of *S. melongena* var. inerne.

Biological material

The biological material in this study was composed of healthy and infested harvested fruits from three varieties *Solanum* spp. (Solanaceae): *S. aethiopicum* var. zong with less sweet fruits (Figure 1a to c), *S. aethiopicum* var. jakatu sweet (Figure 1d to f) and *Solanum melongena* var. inerne with bitter fruits (Figure 1g to i).

Experimental design

For data collection, experimental gardens were set up at each site. At Okola, the experimental garden consisted in 06 ridges of 10 m x 1 m separated each other by furrow of 0.5 m wide. Each ridge supported 24 plants of the same variety (two ridges per variety), placed on two lines, and separated by 0.80 m. At Koutaba, they

were made of 9 ridges (three ridges per variety). For the two localities, seedlings were obtained from the same nursery set up at the Laboratory of Zoology of the University of Yaoundé I (03°51'35.3"N, 011°30'00.6"E, asl: 770 m).

Sampling method

Biological diversity and abundance of fruit pest insects

Data were collected during 184 sampling days unequally distributed among the two study sites; 112 at Okola and 72 at Koutaba. From the Blooming stage of the earliest variety up to the end of the fruiting period of the latest, plots were visited weekly at Okola and Koutaba in order to assess by count, the number of fruits produced, the number of fruits affected by insects and/or diseases and the number of mature fruits. All mature fruits and those affected were systematically

harvested, individually isolated in labelled bags and brought to the laboratory for further observations. Once in the Laboratory, fruits were weighed and categorised as followed: (i) Fruits attacked by fruit feeding insects, characterised by the presence of entrance/exit holes, (ii) quasi-healthy fruits, with no sign of insect attack, (iii) fruits with other affection symptoms. Fruits with insect attack signs were individually incubated in plastic boxes of appropriate size. Each box was previously provided with wet sand, then covered with a fine gauze and followed up to the emergence of adult insects (Djiéto-Lordon and Aléné, 2006, Djiéto Lordon et al. 2007; Mokam et al., 2014; Heumou et al., 2015).

Fruits of the two other categories were dissected in order to detect any cryptic insect attack (in case of cryptic attacks, they were incubated as above). This process allowed us discriminating healthy fruits, fruits lost by insects' attacks, and fruits lost by other biotic factors. To improve sample collection for the biodiversity study, sampling was extended to peasants' gardens in the neighboring areas. In this particular case, only infested fruits were collected and incubated separately. After the emergence, adult insects from each incubating box were separated on the base of morphological features, counted and preserved dry (Lepidoptera) or in vial tubes provided with 70% alcohol (other taxa) for future identifications.

Assessment of yield loss due to specific fruit pests

The number of healthy and infested fruits per plant variety was recorded at each harvest to calculate the incidence of specific fruits pests on the yield. For this purpose, the ratio of the number of fruits of each cultivated plant which have been attacked over the total number of fruits harvested was used (Heumou et al., 2015). The total number of fruits and the number of infested fruits were recorded from all varieties weekly during the period from June 2010 to October 2011 at Okola and from August 2010 to November 2011 at Koutaba. Damage index from each plant variety was calculated and expressed in percentage using the following formula:

$$ID (\%) = (Nif / Nthf) * 100$$

Where: ID (%) = Damage index; Nif = Number of infested fruits by specific pest; Nthf = Number of total harvested fruits

Identification method

Insect determinations were done at the Laboratory of Zoology of the University of Yaoundé I, and confirmed by the taxonomists of CIRAD/CBGP at Montpellier (France). These determinations were based on various keys, including Delvare and Aberlenc (1989) for insect families in general, White (2006) and White and Elson-Harris (2004) for fruit flies, Wharton and Gilstrap (1983) and Wharton et al. (1992) for parasitoids. The monographs of Bordat and Arvanitakis (2004) and Bordat and Daly (1995) were also used. Voucher specimens were deposited in the collections of the two above cited institutions.

Statistical analysis

After transformation, data were submitted to variance analysis test (ANOVA) using the Statistica software version 6.0. Then, a multiple comparison of means was performed using the Tukey HSD test. These statistics treatments aimed to compare the diversity, the abundance and the incidence of fruit pest insects between species/varieties of *Solanum* from one study site to another and from a season to another. All probabilities were appreciated at the 5% threshold.

RESULTS

Biological diversity of the fruit feeding insects and abundance

A total of 15 insect species belonging to 12 families and 3 orders were recorded from incubated fruits of the three species/varieties of *Solanum* in the two study sites. Orders represented were (i) Lepidoptera with 5 species, (ii) Diptera with 8 species and (iii) Coleoptera with 2 species (Table 1). At the site level, there were weak variations as all the 15 species were recorded at Okola while two species *Hypolycaena phylippus* and *Chrysodeixis chalcites* were absent from Koutaba. It is important to notice that the two species absent from Koutaba are highly polyphagous and weakly represented at Okola. The butterfly *Leucinodes orbonalis* (Lepidoptera: Pyralidae) and the fly *Neosilba* sp. (Diptera: Lonchaeidae) were the most important pests at both the two sites (Table 1). Their relative abundances were higher than those of other fruit pests at both Okola and Koutaba without plant species/variety considerations. At Okola, the relative abundance of the pests did not varied significantly in relation to plants species/varieties. For *S. aethiopicum* var. zong, *S. aethiopicum* var. jakatu and *S. melongena* var. inerme, the relative abundances were: 75.1, 68 and 70.3% for *L. Orbonalis*, 15.5, 17.9 and 18.2% for *Neosilba* sp. respectively while at Koutaba, they were 65.9, 68.84 and 67.6% for *L. orbonalis*, and 19.44, 16.47 and 20.98% for *Neosilba* sp. respectively. Apart from these two main species, other pests were weakly abundant on *Solanum* (≤ 10 and 2%) (Table 1).

Insect orders and families associated with species/varieties of *Solanum*

The ANOVA test for the three orders of fruit pests showed non-significant variation of the relative abundance between the two study sites with Lepidoptera ($F = 0.001$, $DF=1$, $P = 0.96$); Diptera ($F = 0.02$, $DF = 1$, $P = 0.87$) and Coleoptera ($F = 0.001$, $DF = 1$, $P = 0.97$). Lepidopterans were the most represented group, with a relative abundance of 73.98% at Okola and 70.19% at Koutaba, followed by dipterans (25.11% at Okola, 28.95% at Koutaba) and coleopterans (0.9% at Okola and 0.86% at Koutaba) (Figure 2).

At the family level, Pyralidae (Lepidoptera) were the most represented with relative abundances of 71.13% at Okola and 67.44% at Koutaba, followed by Lonchaeidae (Diptera) which contributed for 17.2% at Okola and 18.96% at Koutaba. These two families were followed by Muscidae (Diptera) (4.03% at Okola, 5.64% at Koutaba), Tephritidae (Diptera) (3.4% at Okola, 3.43% at Koutaba) and Tortricidae (Lepidoptera) (2.8% at Okola, 2.4% at Koutaba). The other families showed the lowest abundances throughout the study ($< 1\%$) in the both agroecological sites. Pyralidae and Tortricidae were more

Table 1. Frequencies Distribution of insect's morphospecies recorded from incubated *Solanum* fruits collected from June 2010 to November 2011 with reference to fruit species/variety and study sites.

Orders	Families	Fruit pests species	Contribution of fruit losses Fi (%)					
			Okola (Southern plateau)			Koutaba (Western Highlands)		
			Var. zong	Var. inerme	Var. jakatu	Var. zong	Var. inerme	Var. jakatu
Lepidoptera	Pylalidae	<i>Leucinodes orbonalis</i>	75.10	70.30	68.00	65.9	67.6	68.84
	Tortricidae	<i>Cryptophlebia leucotreta</i>	2.50	3.20	2.72	2.23	2.17	2.82
	Noctuidae	<i>Chrysodeixis chalcites</i>	00	00	0.06	00	00	00
	Noctuidae	<i>Helicoverpa armigera</i>	0.04	00	00	0.11	00	0.9
	Lycaenidae	<i>Hypolycaena phylippus</i>	0.04	00	00	00	00	00
Diptera	Tephritidae	<i>Batrocera (Batrocera) dorsalis</i>	1.88	1.80	2.10	1.56	2.17	1.04
	Tephritidae	<i>Ceratitis (Ceratitis) capitata</i>	0.98	0.90	0.6	1.53	00	1.78
	Tephritidae	<i>Ceratitis (Pterandrus) anonae</i>	0.04	00	0.75	0.3	1.65	0.29
	Lonchaeidae	<i>Neosilba</i> sp.	15.50	18.20	17.90	19.27	20.98	16.47
	Muscidae	<i>Atherigona</i> sp.	2.60	4.80	5.70	6.70	4.89	5.34
	Micropezidae	Gn.1 sp.1	0.50	00	1.00	1.67	00	1.04
	Sarcophagidae	Gn.2 sp.2	0.04	00	0.06	0.04	00	0.06
	Stratiomyidae	Gn.3 sp.3	00	00	0.06	0.04	00	00
Coleoptera	Anthicidae	<i>Formicomus</i> sp.	0.75	0.80	1.00	0.56	0.54	1.38
	Cetonidae	<i>Diplognatha gagates</i>	0.03	00	0.05	0.09	00	0.04
N	12	15	2431 fruits	738 fruits	1466 fruits	1203 fruits	266 fruits	884 fruits

Fi (%) = Relative abundance of fruit pests; var. zong = *S. aethiopicum* var. zong; var. jakatu = *S. aethiopicum* var. jakatu; var. inerme = *S. melongena* var. inerme.

abundant at Okola than at Koutaba while all other families were more abundant at Koutaba than at Okola (Figure 3).

Mean number of individuals per fruit on *Solanum* spp.

In the both study sites, larvae of *L. orbonalis* were present in field during the period of pre-flowering, flowering (on shoot and flowers) and fructification (on fruits) and those of *Neosilba* sp. during fruit maturation only. The means number of pest individual per fruit varied significantly in relation to

fruit species/varieties and pest species.

At Okola, the variation of the mean number of *L. orbonalis* individuals per fruit was highly significant between the three species/varieties of *Solanum* ($F = 18.06$, $DF = 2$, $P = 0.0001$), with 1.51 ± 0.77 individuals per fruit on *S. aethiopicum* var. zong ($N = 1891$ fruits), 1.61 ± 0.82 individuals per fruit on *S. aethiopicum* var. jakatu ($N = 1069$ fruits) and 1.37 ± 0.61 individuals per fruit on *S. melongena* var. inerme ($N = 545$ fruits). Similar trend was observed between the mean number of other fruit pest individuals per fruit ($F = 3.9$, $DF = 2$, $P = 0.02$), with 1.89 ± 1.54 individuals per fruit on *S. aethiopicum* var. zong ($N = 151$ fruits), 2.21

± 2.30 individuals per fruit for *S. aethiopicum* var. jakatu ($N = 115$ fruits) and 1.38 ± 0.97 individuals per fruit for *S. melongena* var. inerme ($N = 52$ fruits). Contrarily, with *Neosilba* sp., the mean number of individuals per fruit did not vary significantly with respect to *Solanum* varieties ($F = 197$, $DF = 2$, $P = 0.13$) (with 4.37 ± 3.7 individuals per fruit for *S. aethiopicum* var. zong, ($N = 389$ fruits), 4.74 ± 4.20 individuals per fruit for *S. aethiopicum* var. jakatu ($N = 282$ fruits) and 3.97 ± 3.27 individuals per fruit for *S. melongena* var. inerme ($N = 141$ fruits). Globally, the highest number of fruit pests per fruit was recorded on *S. aethiopicum* var. jakatu, followed by the one on *S.*

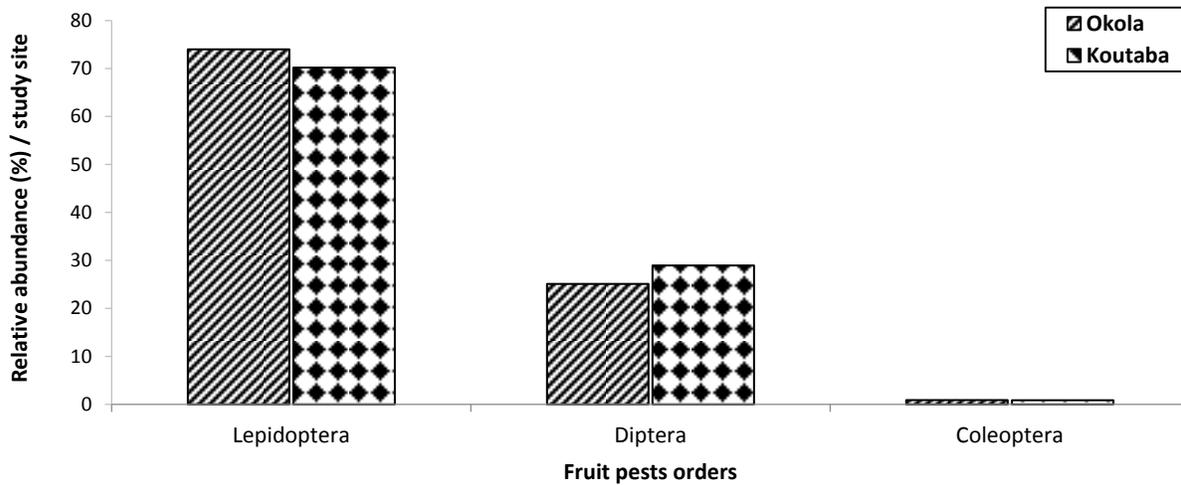


Figure 2. Relative abundance of fruit pest's orders at Okola and Koutaba from June 2010 to October 2011 and from August 2010 to

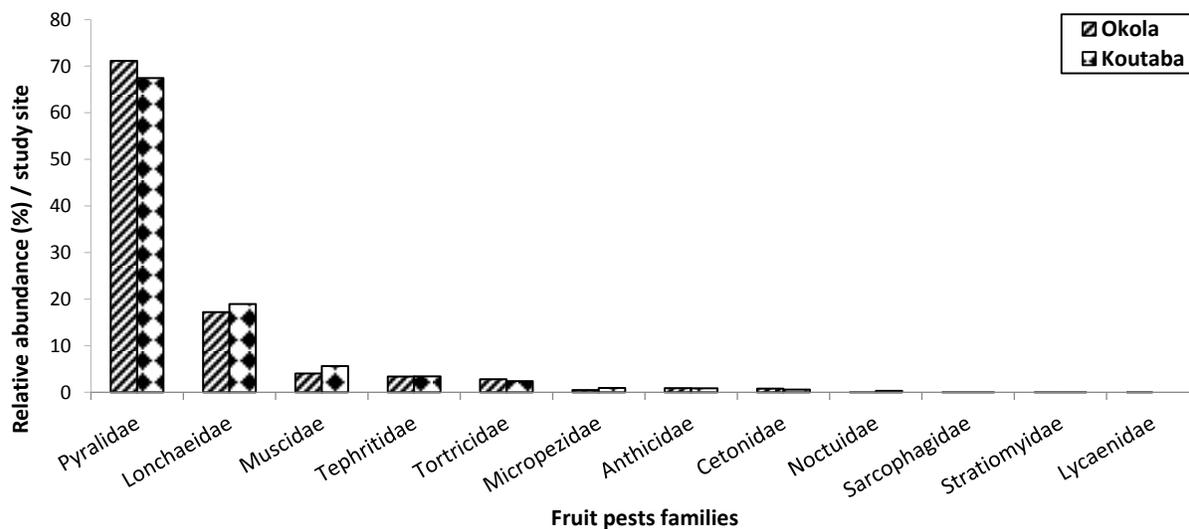


Figure 3. Relative abundance of fruit pest families at Okola and Koutaba from June 2010 to November 2011.

aethiopicum var. zong and finally the one on *S. melongena* var. inerme (Figure 4).

At Koutaba, the mean number of *L. orbonalis* individuals per fruit also varied significantly on *Solanum* species/varieties ($F = 6.24$, $DF = 2$, $P = 0.01$), with 2.62 ± 3.03 individuals per fruit on *S. aethiopicum* var. zong ($N = 896$ fruits), 2.16 ± 1.87 individuals per fruit on *S. aethiopicum* var. jakatu ($N = 674$ fruits) and 2.35 ± 2.38 individuals per fruit on *S. melongena* var. inerme ($N = 184$ fruits). Also, the mean number of individuals per fruit of other pests varied significantly ($F = 3.8$; $DF = 2$; $P = 0.02$), with 2.98 ± 2.48 individuals per fruit on *S. aethiopicum* var. zong ($N = 131$ fruits), 2.40 ± 1.86 individuals per fruit on *S. aethiopicum* var. jakatu ($N = 99$

fruits) and 1.76 ± 0.53 individuals per fruit on *S. melongena* var. inerme ($N = 21$ fruits). Also, the mean number of *Neosilba* sp. individuals per fruit presented a significant variation ($F = 7.7$, $DF = 2$, $P = 0.005$), with 5.84 ± 5.04 individuals per fruit on *S. aethiopicum* var. zong ($N = 176$ fruits); 4.03 ± 3.61 individuals per fruit on *S. melongena* var. inerme ($N = 57$ fruits) and 4.0 ± 3.22 individuals per fruit on *S. aethiopicum* var. jakatu ($N = 111$ fruits).

So, the mean numbers of *L. orbonalis* and *Neosilba* sp. individuals per fruit were high on *S. aethiopicum* var. zong followed by those on *S. melongena* var. inerme and the mean number of other fruit pests was high on *S. aethiopicum* var. zong followed by the one on *S.*

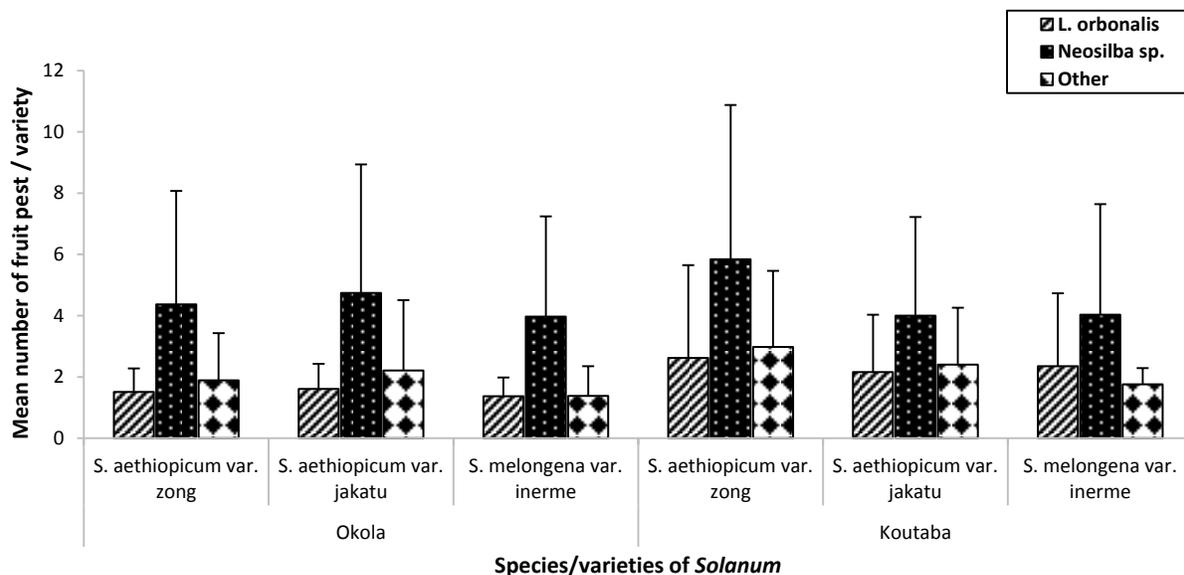


Figure 4. Mean number of individuals/fruit of *L. orbonalis*, *Neosilba* sp. and other fruit pests on *Solanum* spp. at Okola and Koutaba from June 2010 to November 2011.

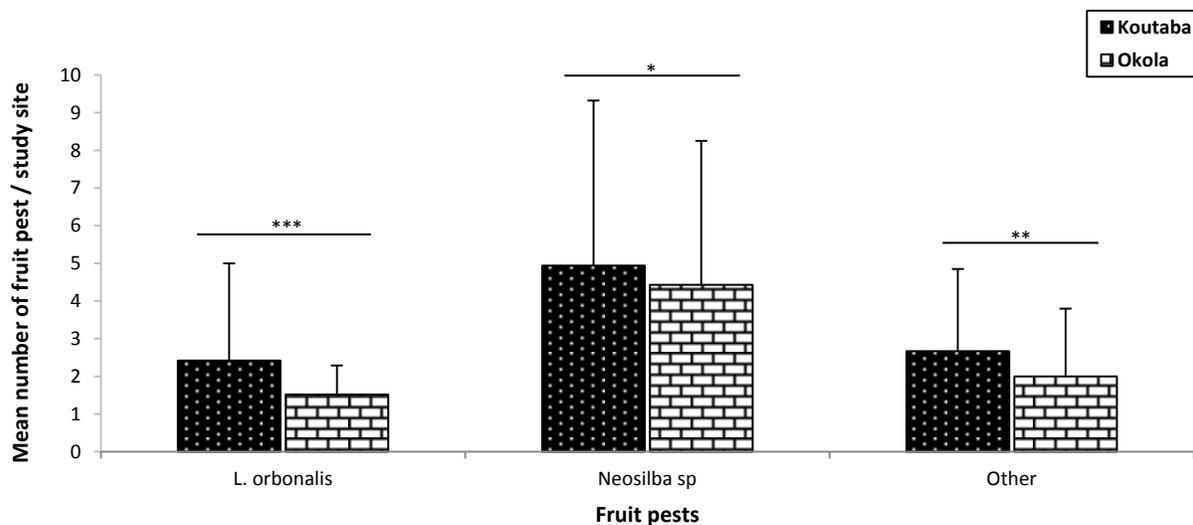


Figure 5. Mean number of *L. orbonalis*, *Neosilba* sp. and other pest's individuals/fruit (*Solanum* spp. cumulated) at Koutaba and Okola from June 2010 to October 2011 and from August 2010 to November 2011, respectively.

aethiopicum var. jakatu (Figure 4).

With the ANOVA, a significant variation was revealed on the mean abundance per fruit of *L. orbonalis* ($F = 360.3$, $DF = 1$, $P = 0.00$), *Neosilba* sp. ($F = 3.9$, $DF = 1$, $P = 0.04$) and other fruit pests ($F = 15.27$, $DF = 1$, $P = 0.0005$) in the two sites:

(i) For *L. orbonalis*, the mean abundance was higher at Koutaba with 2.42 ± 2.58 individuals per fruit (Min = 2.34, Max = 2.49, $N = 1754$ fruits) than at Okola with 1.52 ± 0.77 individuals per fruit (Min = 1.46, Max = 1.57, $N =$

3505 fruits);

(ii) For *Neosilba* sp., the mean abundance was higher at Koutaba with 4.94 ± 4.38 individuals per fruit (Min = 4.52, Max = 5.37, $N = 344$ fruits) than at Okola with 4.43 ± 3.82 individuals per fruit (Min = 4.16, Max = 4.71, $N = 812$ fruits);

(iii) For the other species, the mean abundance was higher at Koutaba than at Okola. These data allowed demonstrating that the mean number of *L. orbonalis*, *Neosilba* sp. and other pests were higher at Koutaba than at Okola (Figure 5).

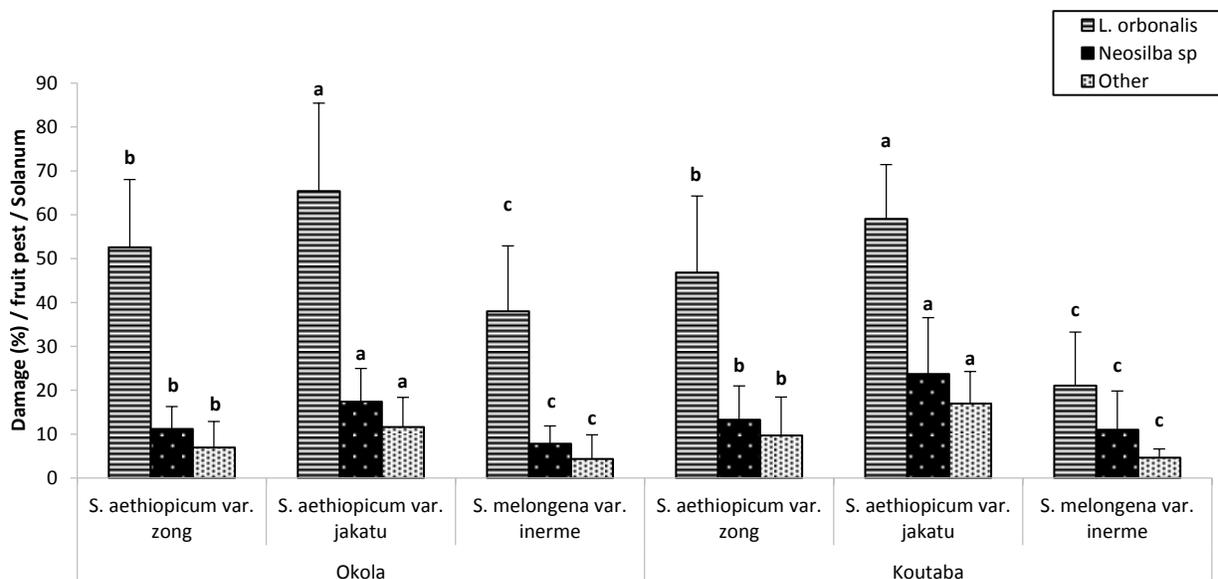


Figure 6. Mean damage due to *L. orbonalis*, *Neosilba* sp. and other fruit pests on *Solanum* spp. at Okola and Koutaba from June 2010 to October 2011 and August 2010 to November 2011 respectively.

Table 2. Damage due to *L. orbonalis*, *Neosilba* sp. and other fruit pests on *Solanum* spp. at Okola and Koutaba from June 2010 to October 2011 and from August 2010 to November 2011.

Fruit pests	%damage index \pm SD due to the pests on fruits		T-value	P-value
	Okola (Southern Plateau)	Koutaba (Western Highlands)		
<i>L. orbonalis</i>	51.99 \pm 20.04% (45.75-58.24)	44.42 \pm 23.57% (35.10-53.74)	1.42	0.15 ^{ns}
<i>Neosilba</i> sp.	12.14 \pm 6.91% (9.99-14.3)	16.04 \pm 11.17% (11.58-20.42)	-1.77	0.08 ^{ns}
Other pests	7.64 \pm 6.66% (5.56-9.72)	10.71 \pm 8.01% (7.54-13.88)	-1.72	0.09 ^{ns}
Mean \pm SD	23.92 \pm 9.47%	22.91 \pm 9.94%	-	-

ns = non-significant ($p \geq 0.05$).

Damage due to specific fruit pests on *Solanum* spp.

The losses of young fruits of *Solanum* spp. in the present study were mainly caused either by the borer *L. orbonalis* or the black fruit fly *Neosilba* sp. and sometimes the both. Then, the two insect species could be regarded as the main causes of fruit losses on the three varieties. The presence of other pest species was so far not neglected despite the fact that their injuriousness in different sites remained weak. It could however cause significant damage in other agroecological zones. So the pattern of damage caused by each species was as follow:

1. *Leucinodes orbonalis*: At Okola, the mean damage index per month due to *L. orbonalis* showed a significant variation on *Solanum* species/varieties ($F = 9.12$, $DF = 2$, $P = 0.005$) with $52.58 \pm 15.46\%$ (Min = 43.65%, Max = 61.51%, $N = 14$ months) on *S. aethiopicum* var. zong, $65.39 \pm 20.06\%$ (Min = 53.8%, Max = 76.97%, $N = 14$ months) on *S. aethiopicum* var. jakatu and with 38.01

$\pm 14.88\%$ (Min = 29.42%, Max = 46.61%, $N = 14$ months) on *S. melongena* var. inerme.

At Koutaba, the mean damage index per month due to *L. orbonalis* showed a significant variation on the *Solanum* species/varieties ($F = 16.73$, $DF = 2$, $P = 0.0028$) with $46.82 \pm 17.44\%$ (Min = 33.41%, Max = 60.23%, $N = 9$ months), $59.04 \pm 12.39\%$ (Min = 49.51%, Max = 68.57%, $N = 9$ months) and $21.06 \pm 12.19\%$ (Min = 11.68%, Max = 30.44%, $N = 9$ months) respectively on *S. aethiopicum* var. zong, *S. aethiopicum* var. jakatu and *S. melongena* var. inerme (Figure 6).

By comparing this value from the two sites using the Student test, there was no significant difference ($t = 1.42$, $P = 0.15$) (Table 2).

2. *Neosilba* sp.: At Okola, mean damage index due to this pest showed a significant variation on the *Solanum* species/varieties ($DF = 2$, $F = 10.02$, $P = 0.003$) with $11.19 \pm 5.10\%$ (Min = 8.24%, Max = 14.17%, $N = 14$ months) on *S. aethiopicum* var. zong, $17.42 \pm 7.55\%$ (Min = 13.06%, Max = 21.78%, $N = 14$ months) on the *S.*

aethiopicum var. jakatu and $7.81 \pm 4.05\%$ (Min = 5.47%, Max = 10.15%, N = 14 months) on *S. melongena* var. inerme.

At Koutaba, the mean damage index due to *Neosilba* sp. showed a significant difference on the *Solanum* species/varieties ($F = 4.10$, $DF = 2$, $P = 0.029$) with $13.27 \pm 7.71\%$ (Min = 7.34%, Max = 19.20%, N = 9 months), $23.72 \pm 12.84\%$ (Min = 13.85%, Max = 33.59 %, N = 9 months) and $11.01 \pm 8.82\%$ (Min = 4.23%, Max = 17.79%, N = 9 months) on *S. aethiopicum* var. zong, *S. aethiopicum* var. jakatu and *S. melongena* var. inerme respectively (Figure 6).

The comparison of this value from the two sites using the Student test showed no significant difference ($t = -1.77$, $P = 0.08$) (Table 2).

3. Other fruit pests: The mean damage index due to other fruit pests showed a significant variation on *Solanum* species/varieties at Okola and Koutaba ($F = 5.16$, $DF = 2$, $P = 0.01$ and $F = 7.73$, $DF = 2$, $P = 0.002$ respectively). Damage were higher on *S. aethiopicum* var. jakatu in both sites with $11.63 \pm 6.75\%$ (Min = 7.73%, Max = 15.53%, N = 14 months at Okola and $16.97 \pm 7.32\%$ (Min = 11.34%, Max = 22.60%, N = 9 months at Koutaba) (Figure 6).

The mean indexes of damage due to other pests in the two study sites were not significantly different on the two study sites ($t = -1.72$, $P = 0.09$) (Table 2).

According to these results, *L. orbonalis* was the main pest for which the highest damage index was recorded on the three *Solanum* species/varieties in the two sites. This butterfly fly appeared to be one of the most injurious pests on *Solanum* spp. fruits in southern Cameroon, followed somewhat by *Neosilba* sp. This study also reveals that fruits of *S. aethiopicum* var. jakatu were the mostly attacked by the pests at the two sites, followed by fruits of *S. aethiopicum* var. zong. *Solanum melongena* var. inerme was slightly less susceptible than the two others.

DISCUSSION

Biodiversity of fruit pests on species/varieties of *Solanum*

The inventory of fruit pests on the three *Solanum* species/varieties recorded the main pest species and revealed their economic importance. Although some species fed on leaves and stems, they were usually controlled by various chemicals. However, the task was highly difficult for fruit pests since they were hidden inside the carpels of young fruits. Thus, the borer *L. orbonalis*, which was present on all the studied species/varieties in the two study sites, appeared to be the most injurious pest on fruits of *Solanum* species. This borer has been reported in Ghana, Uganda and Nigeria by Schippers(2004) on the same species/varieties. Its young

larvae (13 mm) bore into the fruit and develop living holes which persist after their emergence. These holes induce fruit rot, making them uneatable and then unmarketable. Furthermore, *Neosilba* sp. is known to be the most injurious pest on fruits of *Jatropha curcas* in Brazil by Dias et al. (2012). Apart from these two species, we also found some other fruit flies such as *Atherigona* sp., *Batrocera* (*Batrocera*) *dorsalis*, *Ceratitidis* (*Ceratitidis*) *capitata* and *Ceratitidis* (*Pterandrus*) *anonae*, some other caterpillars such as *C. leucotreta*, *H. armigera* and *C. chalcites* which could be regarded as minor fruit pests. These fruit pests have never been recorded as pest on the plants involved in this study but as main fruit pests on other fruits species. The members of the genus *Ceratitidis*, widespread on the African continent were found on guajava fruits in the region of Yaounde by Ndzana Abanda et al. (2007). These authors and Bwomushana et al. (2008) also found on the same fruit species members of the genus *Batrocera*.

Abundance of fruit pest's insects on *Solanum* spp.

From the present study, *L. orbonalis* and *Neosilba* sp. are recorded as the most abundant species among all other fruit pests associated with species/varieties of *Solanum* at Okola and Koutaba. In both sites, *S. aethiopicum* var. jakatu supported the highest abundance of *L. orbonalis*, *Neosilba* sp. and other pests per fruit followed by *S. aethiopicum* var. zong and finally by *S. melongena* var. inerme. The jakatu and zong are among the most common *Solanum* varieties in Africa and therefore more attractive to various fruit pests (Schippers, 2004). The species *L. orbonalis* was the most abundant pest on the three studied varieties. The variety *S. melongena* inerme presented a relatively low abundance compared to the other two varieties. This low abundance correlated with low attack rate. Mannan et al. (2003) showed that the eggplant variety 'Jumki' was resistant to *L. orbonalis* so that infestation due to this pest on its fruits was low. These authors also noticed that the attacks due to fruit pests were low for this variety because the fruit is smaller than other varieties. Then the variety inerme is therefore unable to contain a large population of fruit pests and due to its bitterness, only a few species of fruit pests able to support the bitter taste was feeding on this variety. Moreover, the mean number of *L. orbonalis* per fruit in both sites is lower than those of *Neosilba* sp. This can be linked to the late colonization of larvae of *Neosilba* sp. after fruits maturation. Some larvae of *L. orbonalis* end their development cycle before fruit maturation while other fruit pests colonized fruits up to maturation. In addition, larvae of some flies secondary colonized fruits and emerged in large number during incubations (e.g. *Neosilba* sp. and other fruit flies such as *Atherigona* sp. which preferred very ripe fruits or fruits at the end of maturation) (Dias et al., 2012). The lower number of *L.*

orbonalis individuals could also be explained by the presence of a high number of parasites associated with larvae during incubations and field predators that would have reduced their populations.

Damage due to fruit pest insects on species/varieties of *Solanum*

S. aethiopicum var. jakatu presented the highest damage among the three varieties followed by *S. aethiopicum* var. zong and finally by *S. aethiopicum* var. inerme. This may be due to the difference in tastes of the studied varieties (*S. aethiopicum* var. jakatu is sweet, *S. aethiopicum* var. zong is moderately sweet and *S. melongena* var. inerme is bitter). Resistance and susceptibility of *Solanum* spp. to fruit feeder insects' attacks could then be due to some biochemical characteristics such as chlorophylls, Phenols and Sugars in fruits (Mannan et al., 2003). Elanchezhyan et al. (2008) reported that the sweet *Solanum* varieties with high rate of chlorophyll and low rate of phenol were infested. This could explain why the *S. aethiopicum* var. jakatu presented the highest damage index. These biochemical parameters can play a great role in the behaviour of *Solanum* spp. vis-à-vis fruit pests attacks (Mofazzel et al., 2002). In *S. melongena* var. inerme, damage were the lowest compared to *S. aethiopicum* var. zong and *S. aethiopicum* var. jakatu. This variety is stronger than *S. aethiopicum* var. zong and *S. aethiopicum* var. jakatu which in turn would be respectively tolerant and susceptible to fruit pests' attacks. Indeed, the study of Mannan et al. (2003) showed that some local varieties of *Solanum* such as the Jumki-1 and Jumki-2 were strongly resistant to *L. orbonalis* whose attack rates ranged from 1 to 10 %, whereas other varieties were weakly resistant (Islampuri-3, BL-34 and Muktakeshi) with infestation rate ranging from 11 to 20 % rate, tolerant (with infestation rates ranging from 21-30 %) and susceptible (with infestation rates ranging from 31 to 40 %). In this way, *S. melongena* var. inerme was resistant to the attacks of *L. orbonalis* with a lower attack rate.

In this study, *L. orbonalis* caused fruits losses on *S. aethiopicum* var. jakatu, var. zong, and *S. melongena* var. inerme in the two study sites. These losses were almost constant from June 2010 to November 2011 and varied on the three species/varieties of *Solanum*. In India, attacks due to *L. orbonalis* were studied on 25 varieties of eggplants and these varieties showed different sensitivities to this fruit pest (Elanchezhyan et al., 2008). It is known that the estimated damage caused by *L. orbonalis* may considerably vary (Djiéto-Lordon et al., 2014). On *S. melongena* for example, Patnaik (2000) reported field damage due to *L. orbonalis* ranged from 47.6 to 85.8%. Mehto et al. (1983) observed a reduction in yield ranged from 50 to 60% and Mall et al. (1992) an average field loss of 13% due to *L. orbonalis*. *Neosilba*

sp. caused also damage on *Solanum* spp. fruits at Okola (12.14%) and Koutaba (16.04%). Infestation due to this pest on *Jatropha* fruit was reported by Dias et al. (2012) in Brazil with 53 pupae/kg of fruit and 0.6 pupae/fruit. According to this author, *Neosilba* sp. was regarded as secondary invader of fruit. *Helicoverpa armigera* obtained on *Solanum* during the study were also observed by Etienne and Delvare (1987) on the fruits of *S. aethiopicum* var. jakatu in Casamance (Senegal). These authors noticed that *H. armigera* did not cause serious damage. Merely, it perforated fruits and was known to cause similar damage on tomato (Appert and Deuse, 1982, 1988).

In the present study, attacks due to *L. orbonalis* and somewhat *Neosilba* sp. were always observed during the study period, and more than half of the harvested fruits of *S. aethiopicum* var. jakatu, var. zong, and *S. melongena* var. inerme were affected in the two sites.

Conclusion

At Okola and Koutaba, 15 and 13 species belonging to three orders were inventoried. *Leucinodes orbonalis* and *Neosilba* sp. were the most abundant and the damages they caused on species/varieties of *Solanum* in both sites were noticeable. The borer *L. orbonalis* was the most injurious. Fruits of *S. aethiopicum* var. jakatu were the most susceptible in the two study sites. Infestation from this pest was due to its larvae which develops in carpel of the young fruits.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The present study was carried out with the financial support of the French Ministry of Foreign Affairs via the program "Corus 2" (Project CORUS 6080). The authors are especially grateful to Mrs. Nji Moussa, Ndaga, Nga Tchanga and other farmers who allowed them to work in their farms and gave them land for setting up trap gardens. Their hospitality during their stay in the various study sites is quite appreciable.

REFERENCES

- Adeyeye EI, Adanlawo IG (2011). Amino acid composition of the ripe fruits of *Solanum aethiopicum* and *Solanum macrocarpon*. Int. J. Pharm. BioSci. 2(2):39-51.
- Appert J, Deuse J (1982). Les ravageurs des cultures vivrières et maraichères sous les tropiques. Maisonneuve et Larose, Paris, France.
- Appert J, Deuse J (1988). Insectes nuisibles aux cultures vivrières maraichères. Maisonneuve et Larose, Paris, France.

- Bordat D, Arvanitakis (2004). Catalogues des Arthropodes des cultures légumières d'Afrique de l'Ouest, Centrale, Mayotte et Réunion. CIRAD, Montpellier. France 291 p.
- Bordat D, Daly P (1995). Catalogue des principaux Arthropodes présents sur les cultures légumières de Nouvelle-Calédonie. CIRAD/Mandat de gestion Nouvelle-Calédonie., Montpellier. France 95 p.
- Bwomushana I, Ekesi S, Gordon I, Ogol GKPO (2008). Host Plants and Host Plant Preference Studies for *Batrocera invadens* (Diptera: Tephritidae) in Kenya, a new Invasive Fruit Fly Species in Africa. Ann. Entomol. Soc. Am. 101(2):331-340.
- Delvare G, Aberlenc HP (1989). Les insectes d'Afrique et d'Amérique tropicale. Clés pour la reconnaissance des familles. Prifas/cirad/Gerdat. Montpellier, France. 302 p.
- Dias NS, Broglio SMF, Santos DS, dos Santos JM, Strikis PC (2012). First record of *Neosilba* (Diptera: Lonchaeidae) on *Jatropha curcus* L. in Brasil. Scientific communication. Arq. Inst. Biol. 79(3):423-424.
- Djiéto-Lordon C, Aléné DC (2002). Inventaire des insectes ravageurs et auxiliaires des cultures maraîchères dans la région de Yaoundé. Rapport – CIRAD Yaoundé P 35.
- Djiéto-Lordon C, Aléné DC (2006). Inventaire diagnostique des insectes de quelques cultures dans les exploitations maraîchères périurbaines dans la région de Yaoundé – Cameroun. In «Pôle de compétence en Partenariat (PCP) Grand Sud Cameroun. Actes atelier de présentation des résultats de recherche participative». IRAD/IRAD. Yaoundé, Cameroun pp. 7-17.
- Djiéto-Lordon C, Heumou CR, Elono Azang PS, Aléné DC, Ngueng AC, Ngassam P (2014). Assessment of pest insects of *Capsicum annuum* L.1753 (Solanaceae) in a cultivation cycle in Yaoundé. Int. J. Biol. Chem. Sci. 8(2):621-632.
- Elanchezhyan K, Murali Baskaran RK, Rajavel DS (2008). Field screening of brinjal varieties on major pests and their natural enemies. J. Biopest 1(2):113-120.
- Etienne J, Delvare G (1987). Les insectes associés au fruit du diakhatu (*Solanum aethiopicum*) en Casamance (Sénégal) : composante de l'entomofaune et phénologie des principaux ravageurs. L'AGRONOMIE TROPICALE, 42-3.
- Franqueville A (1972). Les relations ville-campagne sur la route au nord de Yaoundé. Cah. O.R.S.T.O.M., sér. Sci. Hl. 9(3):337-387.
- Heumou CR, Djiéto-Lordon C, Aléné DC, Elono Azang PS (2015). Diversity and agronomic status of tomato and pepper fruit pests in two agroecological zones of Southern Cameroun: Western Highland and the Southern Plateau of Cameroun. Afr. J. Agric. Res. 10(11):1224-1232.
- Lester RN, Seck A (2004). *Solanum aethiopicum* L., pp. 530-536. In: Grubben G.J.H. and Denton O.A. (Eds.). Ressources végétales de l'Afrique Tropicale 2: Légumes. Fondation PROTA / Backhuys Publishers / CTA, Wageningen-Pays Bas.
- Mall NP, Pandey RS, Singh SV, Singh SK (1992). Seasonal incidence of insect-pests and estimation of the losses caused by shoot and fruit borer on brinjal. Indian J. Ent. 54(3):241-247.
- Mannan MA, Begum A, Rahman MM, Hossain MM (2003). Screening of Local and Exotic Brinjal Varieties/Cultivars for Resistance to Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* Guen. Pak. J. Biol. Sci. 6 (5):488-492.
- Mehto DN, Singh KM, Singh RN, Prasad D (1983). Biology of brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen. Bull. Entomol. 24(2):112-115.
- Messiaen CM (1989). Le potager tropical. 2nd ed. ACCT/CILF. PUF. Paris, France 580 p.
- Mofazzel HM, Shahjahan M, Mosaddeqqe HM, Bari MN (2002). Chlorophyll Contents of Brinjal Plants Influencing the Resistance and Susceptibility to Brinjal Shoot and Fruit borer, *Leucinodes orbonalis* Guenne. Pak. J. Biol. Sci. 5(8):825-829.
- Mokam DG, Djiéto-Lordon C, Bilong Bilong CF (2014). Patterns of species richness and diversity of insects associated with Cucurbit fruits in the Southern part of Cameroun. J. Insect Sci. 14(248):1-9.
- Ndzana Abanda FX, Quilici S, Vayssières JF, Kouodiekong L, Woin N (2007). Inventaire des espèces de mouches des fruits sur goyave dans la région de Yaoundé au Cameroun. Fruits 63(1):19-26.
- Noumi E (1984). Les plantes à épices, à condiments et à arômes du Cameroun: Thèse de Doctorat 3ième cycle en sciences biologiques. Faculté des Sciences, Université de Yaoundé, Cameroun 165 p.
- Patnaik HP (2000). Flower and fruit infestation by brinjal shoot and fruit borer *Leucinodes orbonalis* Guenée. Damage potential vs. weather. Veg. Sci. 27(1):82-83.
- Schippers RR (2004). Légumes africaines indigènes : Présentation des espèces cultivées. Margraf Publishers. CTA, Wageningen, Pays-Bas 482 p.
- Sekara A, Cebula S, Kunicki E (2007). Cultivated eggplants – origin, breeding objectives and genetic resources, a review. Folia Hort. Ann. 19/1:97-114.
- Suchel FG (1988). Les régions climatiques du Cameroun. Les climats du Cameroun. Thèse de Doctorat d'Etat. Université de S^t. Etienne, France 1188 p.
- Tchiégang C, Mbougueng FD (2005). Composition chimique des épices utilisées dans la préparation du Nah poh et du Nkui de l'ouest Cameroun. Tropicultura 23(4):193-200.
- Temple L (2001). Quantification des productions et des échanges de fruits et légumes au Cameroun. Cahiers Agric. 10(2):87-94
- Westphal E, Embrechts J, Mbouemboue PMB, Westphal-Stevens JMC (1981). Agriculture autochtone au Cameroun. Veenman & B.V Wageningen, Pays-Bas 175 p.
- Wharton RA, Gilstrap FE (1983). Key to and status of opiine braconid (Hymenoptera) parasitoids used in biological control of *Ceratitis* and *Dacus* s. l. (Diptera: Tephritidae). Annals of the Entomological Society of America. 76:721-742.
- Wharton RA, Shaw SR, Sharkey NJ, Wahl DB, Woolley JB, Marsh PM, Johnson W (1992). Phylogeny of the subfamilies of the family Braconidae (Hymenoptera: Ichneumonidae). A reassessment. Cladistics 8:199-235.
- White IM (2006). Taxonomy of the *Dacina* (Diptera: Tephritidae) of Africa and the Middle East. Afr. Entomol. Memoir 2:1-156.
- White IM, Elson-Harris MM (2004). Fruit flies of economic significance: their identification and bionomics, London, CAB/ACIAR.